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TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: New Minimum Pavement Marking Retroreflectivity Rule

May 24, 2023

1:00 – 2:30 PM

NOVEMBER 2022 UPDATE

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Andie Pitchford at TRBwebinar@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Program. Credit earned on completion of this program will be reported to RCEP at RCEP.net. A certificate of completion will be issued to each participant. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the RCEP.

ENGINEERING



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Purpose Statement

A new Federal Highway Administration (FHWA) pavement marking retroreflectivity rule seeks to raise the bar for safety. This webinar will discuss the details of the rule and methods for compliance.

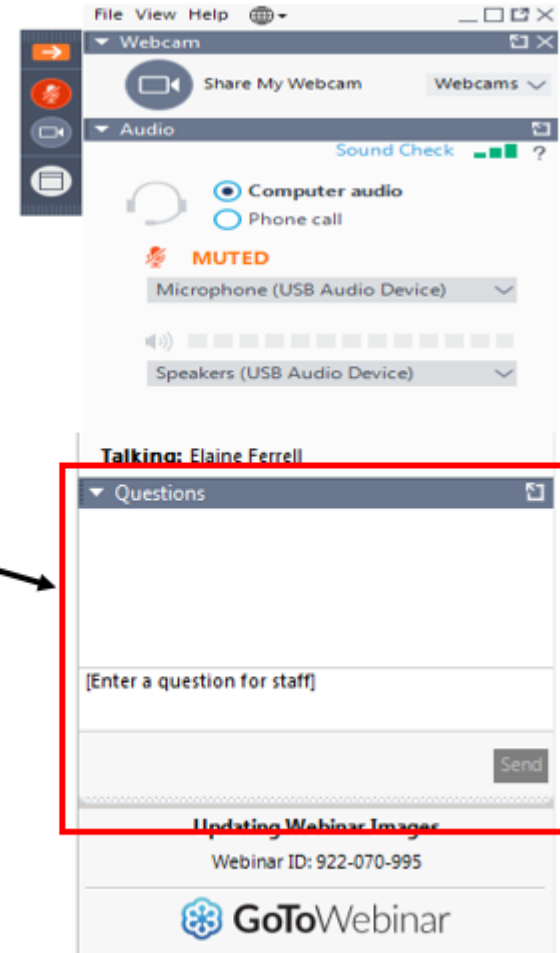
Learning Objectives

At the end of this webinar, you will be able to:

- (1) Identify details for the new minimum retroreflectivity rule for pavement markings
- (2) Apply practices to assist with compliance given a set of budget constraints

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows



Today's presenters



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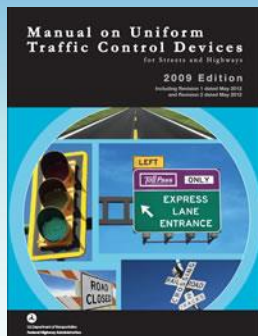
U.S. Department
of Transportation
**Federal Highway
Administration**

**NATIONAL
ACADEMIES** *Sciences
Engineering
Medicine*



Final Rule: Maintaining Pavement Marking Retroreflectivity

George Merritt
May 24th, 2023



U.S. Department of Transportation
Federal Highway Administration

ZERO IS OUR GOAL
A SAFE SYSTEM IS HOW WE GET THERE

<http://safety.fhwa.dot.gov>



Disclaimers

Except for any statutes or regulations cited, the contents of this presentation do not have the force and effect of law and are not meant to bind the States or the public in any way. This presentation is intended only to provide information regarding existing requirements under the law or agency policies.

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Unless otherwise indicated, FHWA is the source for all images in this presentation.



Final Rule



Federal Register

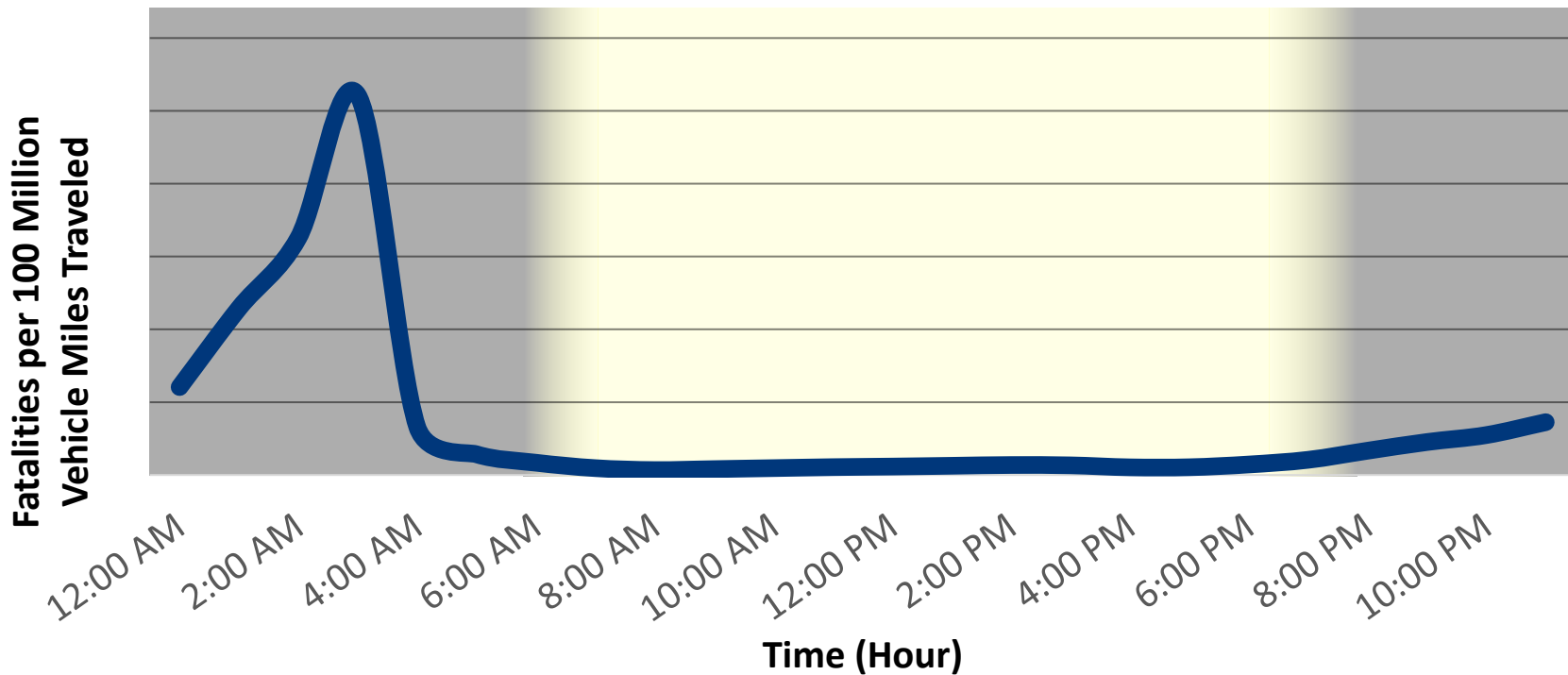
- Federal Register – August 5, 2022
- 2009 MUTCD Revision 3
- Maintaining Minimum Pavement Marking Retroreflectivity
- Effective date: September 6, 2022
- <https://www.federalregister.gov/d/2022-16781>





The Problem: Nighttime vs. Daytime Fatality Rates

Fatality Rate per Hundred Million VMT by Hour (2015-2019)





Why is Retroreflectivity Important?

Visibility is critical for nighttime driving

Daytime - many cues available



Nighttime - few cues remain





Revisions to Three Sections of the MUTCD

- Section 3A.03 – Maintaining Minimum Retroreflectivity
- Introduction – Compliance Date (Table I-2)
- Section 1A.11 – Methods Publication





MUTCD Section 3A.03

Section 3A.03 Maintaining Minimum Pavement Marking Retroreflectivity





MUTCD Section 3A.03 Paragraph 1

Standard:

Except as provided in Paragraph 5, a method designed to maintain retroreflectivity at or above 50 mcd/m²/lx under dry conditions shall be used for longitudinal markings on roadways with speed limits of 35 mph or greater.

NOTE: mcd/m²/lx means millicandelas per square meter per lux





MUTCD Section 3A.03 Paragraph 2

Guidance:

Except as provided in Paragraph 5, a method designed to maintain retroreflectivity at or above 100 mcd/m²/lx under dry conditions should be used for longitudinal markings on roadways with limits of 70 mph or greater.

NOTE: mcd/m²/lx means millicandelas per square meter per lux





MUTCD Section 3A.03 - Summary of Values

Maintaining Minimum Retroreflectivity

Standard: 50 mcd/m²/lx – Speed limits 35 mph or greater.

Guidance: 100 mcd/m²/lx – Speed limits 70 mph or greater

NOTE: mcd/m²/lx means millicandelas per square meter per
lux



MUTCD Section 3A.03 Paragraph 3

Guidance:

The method used to maintain retroreflectivity should be one or more of those described in “Methods for Maintaining Pavement Marking Retroreflectivity” (see Section 1A.11) or developed from an engineering study based on the values in Paragraphs 1 and 2.





MUTCD Section 3A.03 Paragraph 4

Support:

Retroreflectivity levels for pavement markings are measured with an entrance angle of 88.76 degrees and an observation angle of 1.05 degrees. This geometry is also referred to as 30-meter geometry. The units of pavement marking retroreflectivity are reported in $\text{mcd}/\text{m}^2/\text{lx}$, which means millicandelas per square meter per lux.





MUTCD Section 3A.03 Paragraph 5: Option

Optional Exclusions to an Agency's Method:

- Where ambient illumination assures that the markings are adequately visible
- Streets or highways that have an ADT of less than 6,000 vehicles per day
- Dotted extension lines (Section 3B.08)
- Curb markings
- Parking space markings
- Shared-use path markings





MUTCD Section 3A.03 Paragraph 6: Support

Exclusions (Non-Longitudinal Markings):

- Transverse markings
- Word, symbol, and arrow markings
- Crosswalk markings
- Chevron, diagonal, and crosshatch markings





MUTCD Section 3A.03 Paragraph 7: Support

Special Circumstances:

- Isolated locations of abnormal degradation
- Periods preceding imminent resurfacing or reconstruction
- Unanticipated events such as...
- Snow maintenance operations





Summary of Minimum Values for Longitudinal Markings

	Standard		<i>Guidance</i>
Speed Limit	<35 mph	≥35 mph	≥70 mph
Retroreflectivity Level	n/a	50 mcd/m²/lx	100 mcd/m²/lx

Optional Exclusions:

- Ambient illumination
- Less than 6,000 ADT
- Dotted extension lines
- Curb markings
- Parking spaces
- Shared-use paths





Methods for Maintaining Pavement Marking Retroreflectivity

https://safety.fhwa.dot.gov/roadway_dept/night_visib/pm_methods_fhwasa22028.pdf

- Measured Retroreflectivity
- Consistent Parameters Nighttime Visual Inspection
- Calibrated Pavement Markings Nighttime Visual Inspection
- Service Life Based on Historical Data
- Service Life Based on Monitored Markings
- Other Methods (combination or based on engineering study)





Measured Retroreflectivity Method

- Measure markings with standard retroreflectometer (handheld or mobile)
- Compare measured values with minimum values
- Often combined with other methods

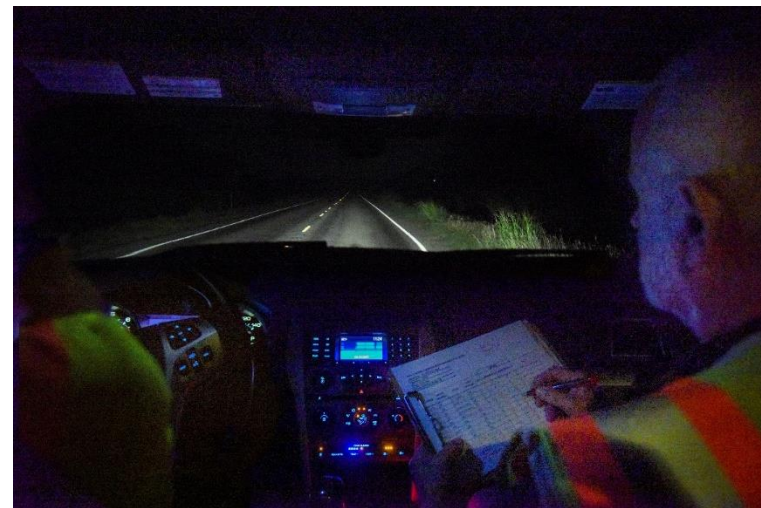




Consistent Parameters Nighttime Visual Inspection Method

Tie to minimum values by using consistent parameters as used to develop the minimum values:

- Trained inspector, older driver (60+)
- Passenger vehicle
 - (sedan preferred)
- Low beam headlamps
 - (properly aimed)





Calibrated Pavement Markings Nighttime Visual Inspection Method

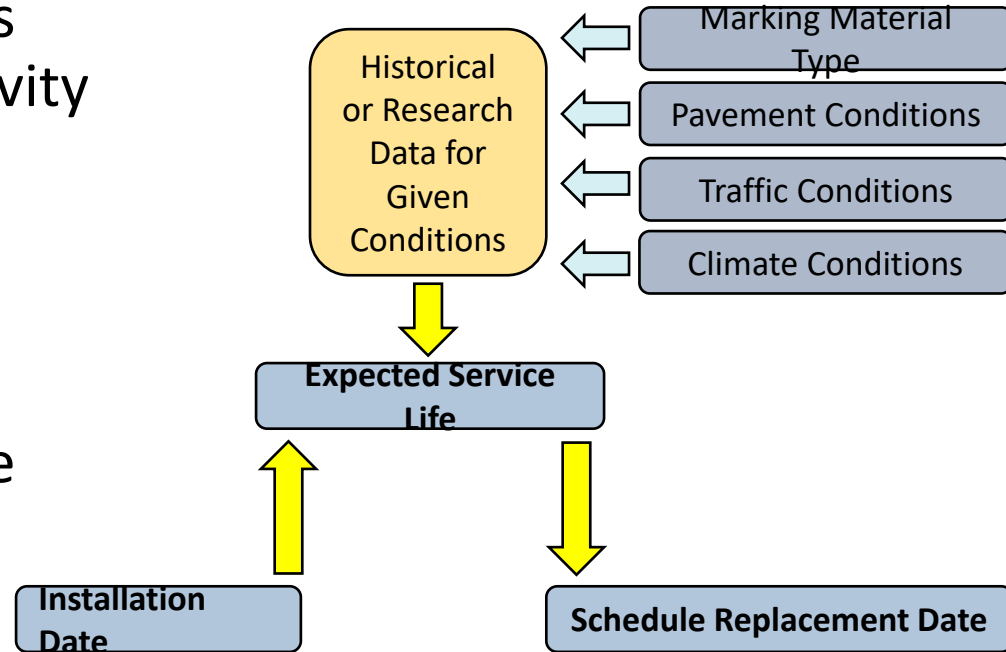
- Calibrate” eyes with calibration markings
- Calibration markings have known retroreflectivity that is at or above the minimums
- Evaluate in-service markings compared to the calibration markings





Service Life Based on Historical Data Method

- Based on installation dates and historical retroreflectivity data or research results
- Markings are replaced at specific intervals
- Considers conditions that impact marking service life





Service Life Based on Monitored Markings Method

- Based on monitoring a sample of a larger group of “similar” markings through measured retroreflectivity or nighttime visual inspection
- All markings in the “similar” group are replaced when the monitored markings are near or at the minimum values



2019 Installations



2019 Comparison
Monitored Markings



2020 Installations



2020 Comparison
Monitored Markings

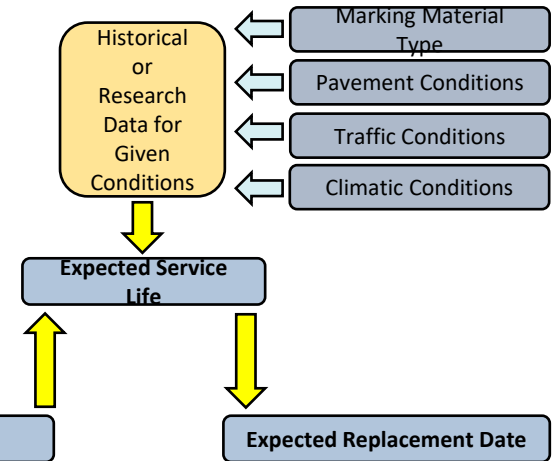


State DOT
Maintained Roads



Other Methods

- Combine Methods
- Develop a method based on engineering studies that are based on minimum values





'Techniques' NOT Recommended as Methods

- Sun Over the Shoulder
- Comparison Panel
- Lane Line Count
- Windshield Marking
- Control Markings
- Comparison Light Box





Markings Must Be Maintained



Retroreflectivity requirements in Section 3A.02 apply to ALL pavement markings, even if an agency chooses not to include all markings in their method:

Standard:

Markings that must be visible at night shall be retroreflective unless ambient illumination assures that the markings are adequately visible. All markings on Interstate highways shall be retroreflective.





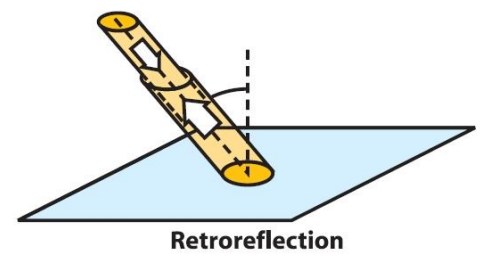
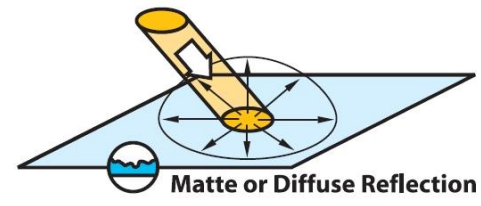
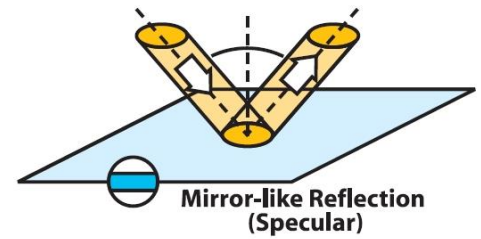
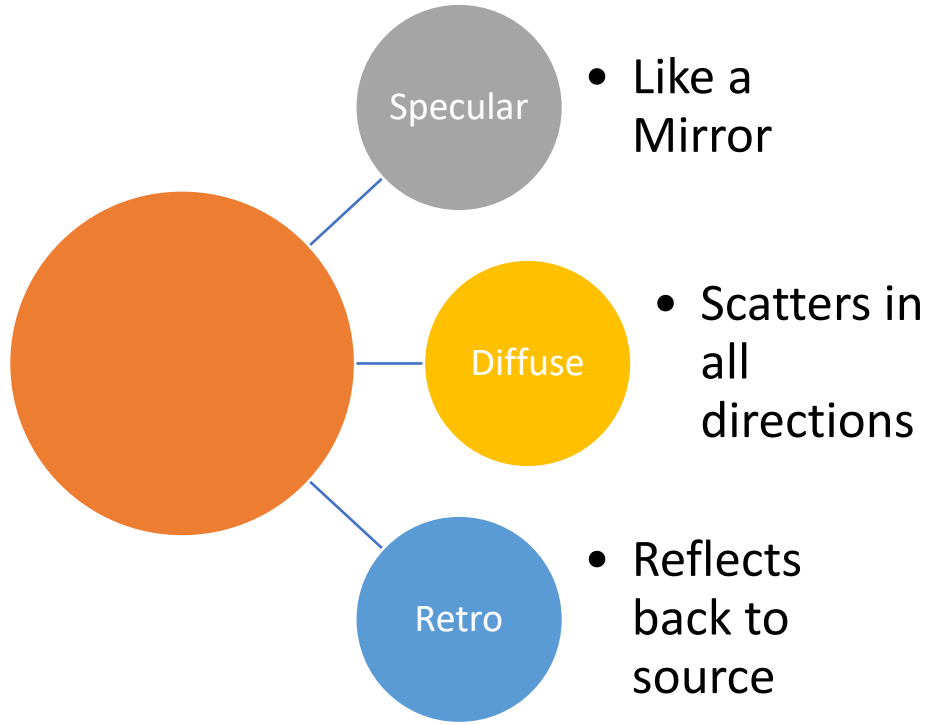
Resources

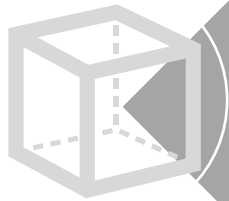
- **FHWA Nighttime Visibility Website:**
 - www.fhwa.dot.gov/retro
- **MUTCD Website:**
 - <http://mutcd.fhwa.dot.gov>
- **Methods for Maintaining Pavement Marking Retroreflectivity**
 - https://safety.fhwa.dot.gov/roadway_dept/night_visib/pm_methods_fhwasa22028.pdf
- **FHWA Pavement Marking Retroreflectivity Site**
 - https://safety.fhwa.dot.gov/roadway_dept/night_visib/pavement-markings.cfm



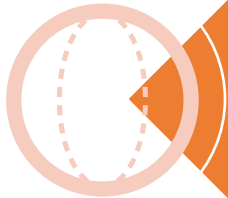
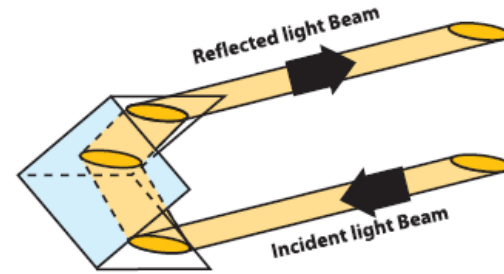
*Using a
Retroreflectometer to
Meet the MUTCD
Pavement Marking
Retroreflectivity
Requirements*



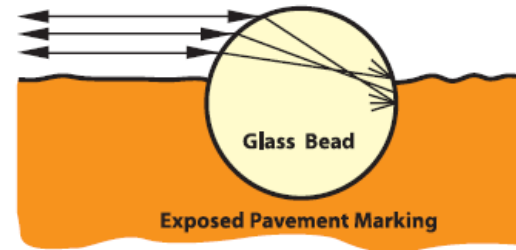


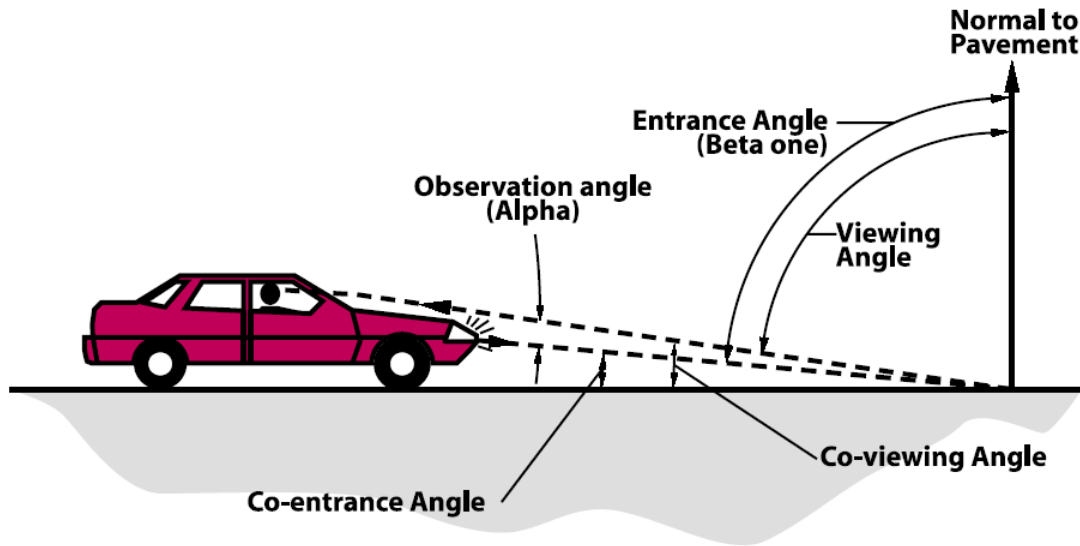


Prismatic
Cube
Corners



Glass
Beads





Units of Retroreflection for pavement markings are

$\text{mcd/m}^2/\text{lux}$

Don't worry if you don't know what that means.

Standard Car Geometry:

Driver Eye Height = 1.20 meters (3.9 feet)

Car Headlamp Height = 0.65 meters (2.1 feet)



Over the past 40 years, approximately 2/3rds of the fatal crashes have occurred at night



Nighttime fatal crash rate is about three times higher than during the day



Encourage agencies to improve pavement markings



Improves performance of automated vehicle functions



U.S. Department
of Transportation
**National Highway
Traffic Safety
Administration**

DOT HS 813 266



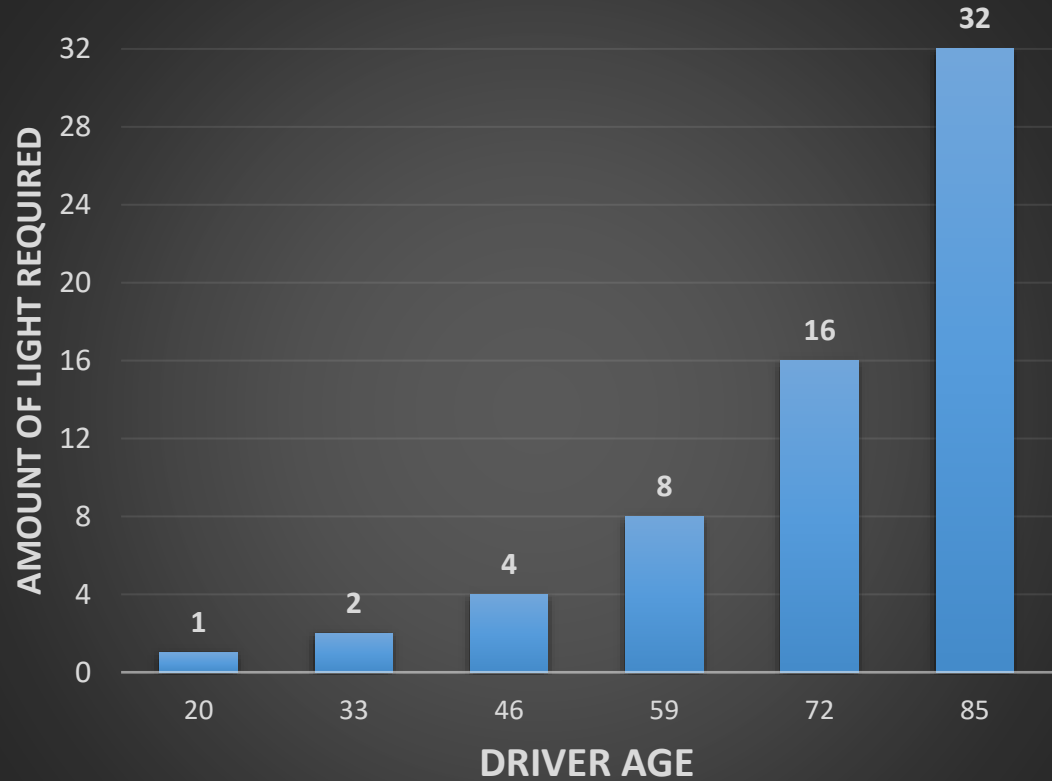
March 2023

Table 7. Passenger Vehicle Occupants Involved in Fatal Crashes, by Restraint Use, Survival Status and Time of Day, 2019 and 2020


Description	2019	2020	Change	% Change	Restraint Use Percent Based on Known Use	
					2019	2020
Passenger Vehicle Occupants Killed						
Total	22,372	23,824	+1,452	+6.5%		
Restrained	10,891	10,483	-408	-3.7%	53%	49%
Unrestrained	9,523	10,893	+1,370	+14%	47%	51%
Unknown	1,958	2,448	+490	+25%		
Time of Day						
Daytime	11,840	11,787	-53	-0.4%		
Restrained	6,678	6,113	-565	-8.5%	61%	56%
Unrestrained	4,317	4,740	+423	+9.8%	39%	44%
Unknown	845	934	+89	+11%		
Nighttime	10,345	11,846	+1,501	+15%		
Restrained	4,150	4,319	+169	+4.1%	45%	42%
Unrestrained	5,110	6,034	+924	+18%	55%	58%
Unknown	1,085	1,493	+408	+38%		

Starting at age 20 the amount of light required to see doubles every 13 years

A 72 year old driver requires 16x more light to see than a 20 year old




Simplified visualization of the difference drivers of different ages will see if the lighting remains constant



20 year old

A nighttime view of a road with a yellow center line and a white edge line. The road is brightly lit, and the lane markings and a yellow sign on the right are clearly visible.



33 year old

A nighttime view of a road with a yellow center line and a white edge line. The lighting is slightly dimmer than the 20-year-old view, but the lane markings and a yellow sign on the right are still clearly visible.



46 year old

A nighttime view of a road with a yellow center line and a white edge line. The lighting is noticeably dimmer, and the lane markings and a yellow sign on the right are less distinct.



59 year old

A nighttime view of a road with a yellow center line and a white edge line. The lighting is very dim, and the lane markings and a yellow sign on the right are barely visible.



72 year old

A nighttime view of a road with a yellow center line and a white edge line. The lighting is extremely dim, and the lane markings and a yellow sign on the right are almost completely invisible.



85 year old

A nighttime view of a road with a yellow center line and a white edge line. The lighting is so dim that the lane markings and a yellow sign on the right are nearly impossible to discern.

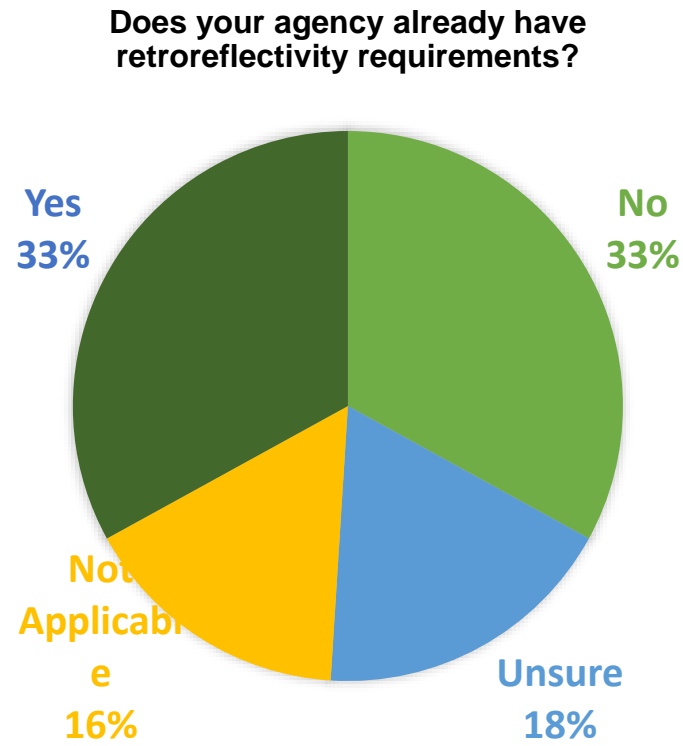
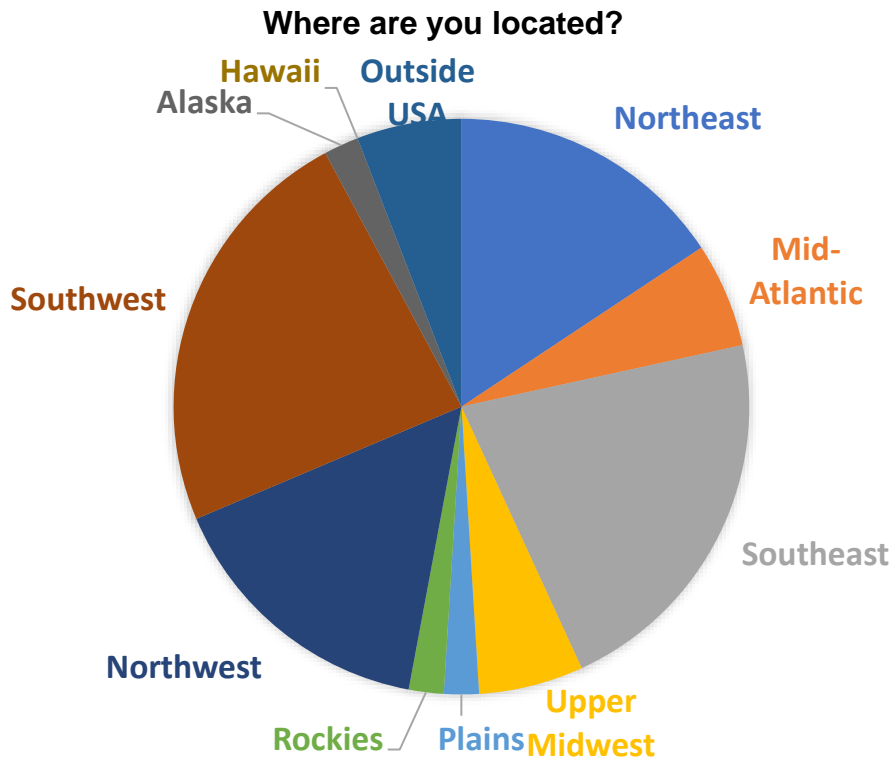
Service Life Replacement Based on
Historical Data

Service Life Replacement Based on
Monitored Markings

Consistent Parameters Nighttime
Visual Inspections

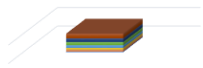
Calibrated Pavement Markings
Nighttime Visual Inspections

**Measured
Retroreflectivity**



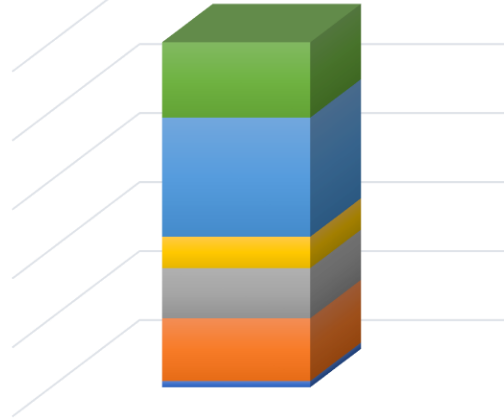
*Survey of public officials and contractors was performed in October 2022

Main method of pavement marking assessment



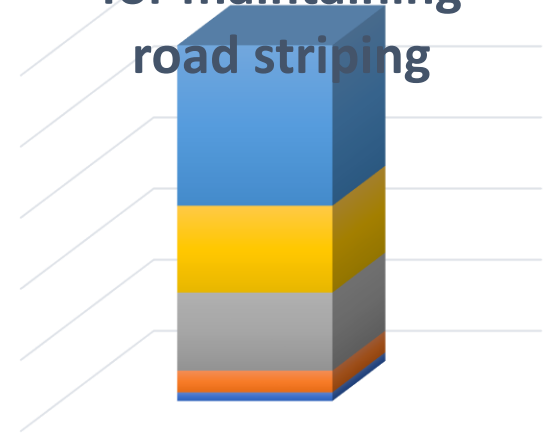
- Daytime Visual
- Nighttime Visual
- Retroreflectometer (handheld)

How markings are inventoried



- Inventoried and managed via GIS
- Inventoried Manually

Department goals for maintaining road striping



- Being MUTCD Compliant
- Proactively monitoring retroreflectivity

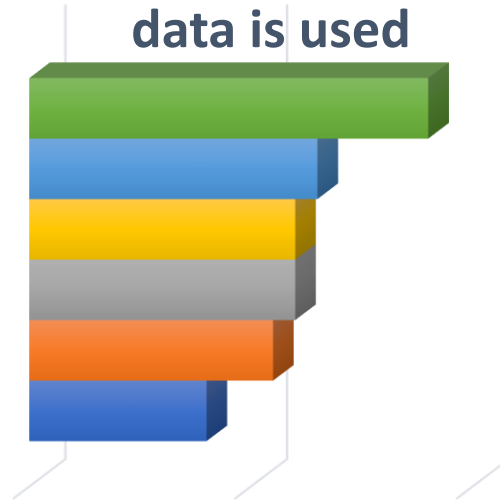
*Survey of public officials and contractors was performed in October 2022

What attributes are you collecting?



- Installation date
- Location on road
- Stripe Width
- Material type (bead, binder, etc.)

How collected data is used



- Creating a prioritized list for maintenance/restriping
- Budgeting decisions

How often roads are typically restriped



- Every 12-24 months

There are two types of pavement marking retroreflectometers

- Handheld



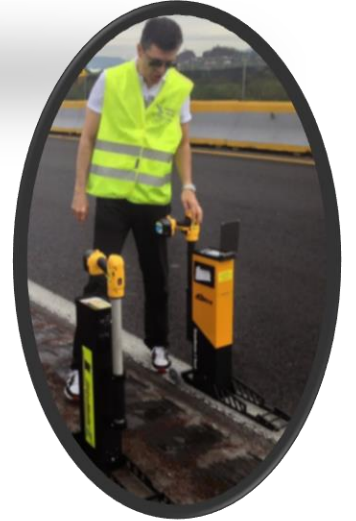
- Mobile



Either type can be used to monitor pavement marking retroreflectivity, but methods are different

Using a Handheld Retroreflectometer

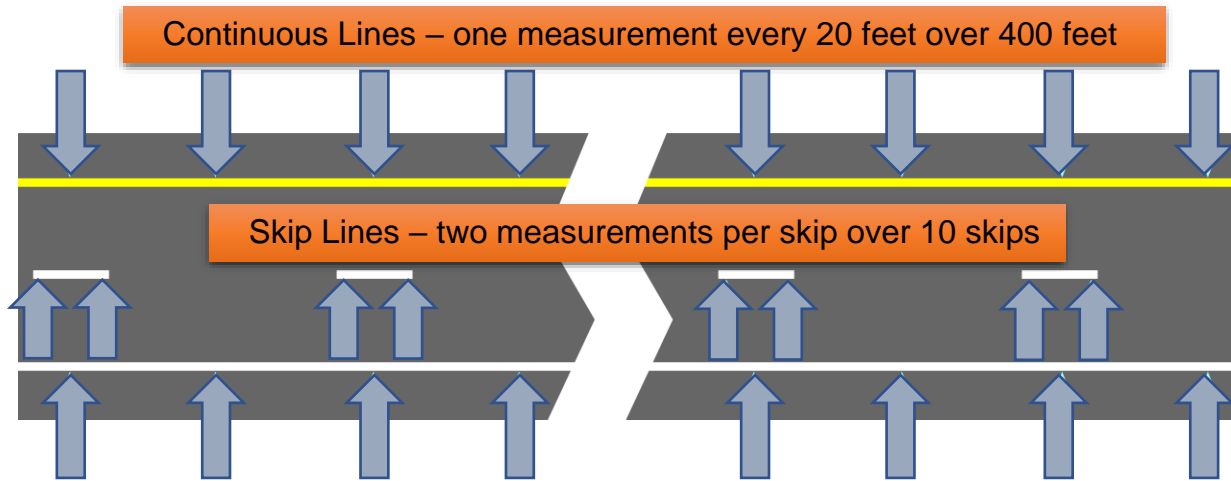
- ASTM D7585/D7585M outlines a good procedure for performing surveys using a handheld retroreflectometer.
- It uses a tiered measurement system so that less time is spent measuring pavement markings that are performing well and more time is spent in the areas that may need to be re-striped.
- Measurements shall always be made in the direction of travel which means centerlines on undivided roads need to be measured in both directions.



Using a Handheld Retroreflectometer

- To evaluate a marking, 20 measurements shall be made at a randomly located, representative ~400 foot section of road.
- For evaluations of markings 2 miles or less, one randomly location section will suffice
- For evaluations of markings 2 to 10 miles long, 3 randomly located sections shall be chosen (60 total measurements)
- For evaluations of markings longer than 10 miles, a minimum of 3 sections of measurements shall be used, but preferably more (e.g. 3 sections per 10 miles)





- Report should include:
 - Test date and time
 - Operator name and contact info
 - Pavement marking characteristics
 - Retroreflectivity
 - GPS Location
 - Color
- Optional:
 - Binder Type
 - Bead Type / Bead Size
 - Install date
 - Location on Road
 - Color Coded Map

RoadVista Instrument Control Application

Download Data Select Com Port Clear Memory KML Options Diagnostics Timing

Open Data File Save Data File Configure Instrument CSV Options View Log Info Firmware Update

Handheld Data.csv

Field Descr	Value	Record #	Date-Tm	Latitude	Longitude	Accuracy (m)	Temp	RH	LOR	Lane #	LOR-Sic	Assets	Stripe Width	Retro Reading	Retro Std. Deviatio	Retro Pass or Fail	Retro Pass/Fail Limit Value	Qd Reading	Qd Std. Deviatio	Qd Pass
File#	50	1	7/21/...	32 49...	117 8...	5.5	81	57	EdgeLine			26	4	159	0	FAIL	200			
Model	STRIPEMASTER 2...	2	7/21/...	32 49...	117 8...	5.5	85	54	EdgeLine			26	4	113	0	FAIL	200			
Serial#	GF1001	3	7/21/...	32 49...	117 8...	5.3	85	53	EdgeLine			26	4	201	0	PASS	200			
CPU Firmware Vers...	2.28	4	7/21/...	32 49...	117 8...	5.3	85	53	EdgeLine			26	4	209	0	PASS	200			
GPU Firmware Vers...	2.28	5	7/21/...	32 49...	117 8...	5.5	85	53	EdgeLine			26	4	208	0	PASS	200			
Calibration Std SN#	1001	6	7/21/...	32 49...	117 8...	7.6	86	53	EdgeLine			26	4	240	0	PASS	200			
Calibration Std Value	159	7	7/21/...	32 49...	117 8...	6.7	86	53	EdgeLine			26	4	240	0	PASS	200			
Records	23	8	7/21/...	32 49...	117 8...	6.1	86	53	EdgeLine			26	4	240	0	PASS	200			
User	George	9	7/21/...	32 49...	117 8...	15	85	54	EdgeLine			26	4	214	0	PASS	200			
Location	Tech Road	10	7/21/...	32 49...	117 8...	10	85	54	EdgeLine			26	4	217	0	PASS	200			
Material Thickness	25	11	7/21/...	32 49...	117 8...	9.6	85	54	EdgeLine			26	4	217	0	PASS	200			
Thickness Units	mil	12	7/21/...	32 49...	117 8...	20	86	53	EdgeLine			26	4	217	0	PASS	200			
Unused_1		13	7/21/...	32 49...	117 8...	17	86	53	EdgeLine			26	4	224	0	PASS	200			
Install Date	6/1/2015	14	7/21/...	32 49...	117 8...	16	86	53	EdgeLine			26	4	223	0	PASS	200			
Note-1		15	7/21/...	32 49...	117 7...	9	86	53	EdgeLine			26	4	265	0	PASS	200			
Note-2		16	7/21/...	32 49...	117 7...	7.7	86	53	EdgeLine			26	4	265	0	PASS	200			
Note-3		17	7/21/...	32 49...	117 7...	7.2	86	53	EdgeLine			26	4	276	0	PASS	200			
Cal. Time	7/21/2015 23:38	18	7/21/...	32 49...	117 7...	7.1	85	53	EdgeLine			26	4	263	0	PASS	200			
Calibration Error	0	19	7/21/...	32 49...	117 7...	6.7	85	53	EdgeLine			26	4	272	0	PASS	200			
Stripe Width Units	in.	20	7/21/...	32 49...	117 7...	10	85	53	EdgeLine			26	4	198	0	FAIL	200			
Qd Units	mcd/m^2/k	21	7/21/...	32 49...	117 7...	9.8	85	53	EdgeLine			26	4	192	0	FAIL	200			
Temperature Units	F	22	7/21/...	32 49...	117 7...	9.1	85	53	EdgeLine			26	4	175	0	FAIL	200			
File Retro Average	217	23	7/21/...	32 49...	117 7...	9	85	53	EdgeLine			26	4	183	0	FAIL	200			
File Qd Average	0																			
GPS Format	ddd mm.mmmm																			
Asset 1 Descr.	Thermoplastic																			

About Processing Record 23

Google Earth Pro

File Edit View Tools Add Help

Search

Get Directions History

Places

- My Places
- Sightseeing Tour
 - Make sure 3D Buildings layer is checked
- Temporary Places
- Handheld Data.kml

Layers

- Primary Database
- Announcements
- Borders and Labels
- Places
- Photos
- Roads
- 3D Buildings
- Weather
- Gallery
- More
- Terrain

Google Earth

Security Data: 7/21/2021 82°49'25.53" N 117°08'20.41" W elev 0 ft eye alt 3478 ft

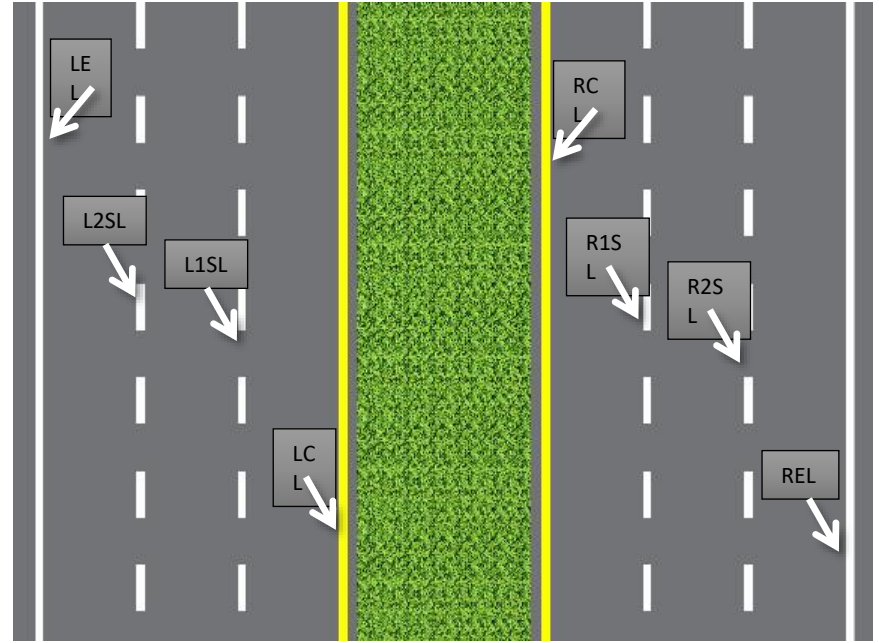
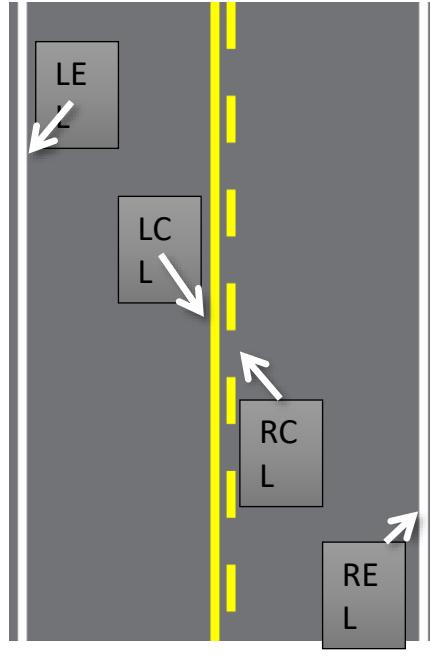
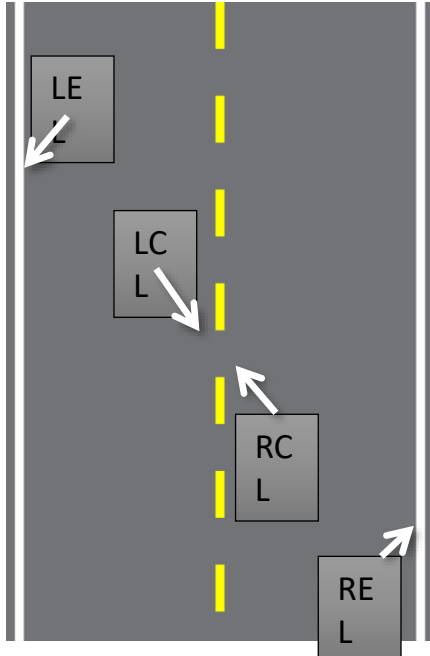
Using a Mobile Retroreflectometer

AWA 519-1010384 formerly 519-1010384
can be a very simple or complex
measurement of the retroreflectivity of
pavement marking materials using a
mobile retroreflectometer. The
configuration and mobile retroreflectometer
unit (MRU) is available that allow you to
measure both sides of the lane
simultaneously. The amount of
continuous measurements of the
line and averages them together in
No need to randomly select
different sections – just drive. The
instrument does the rest.

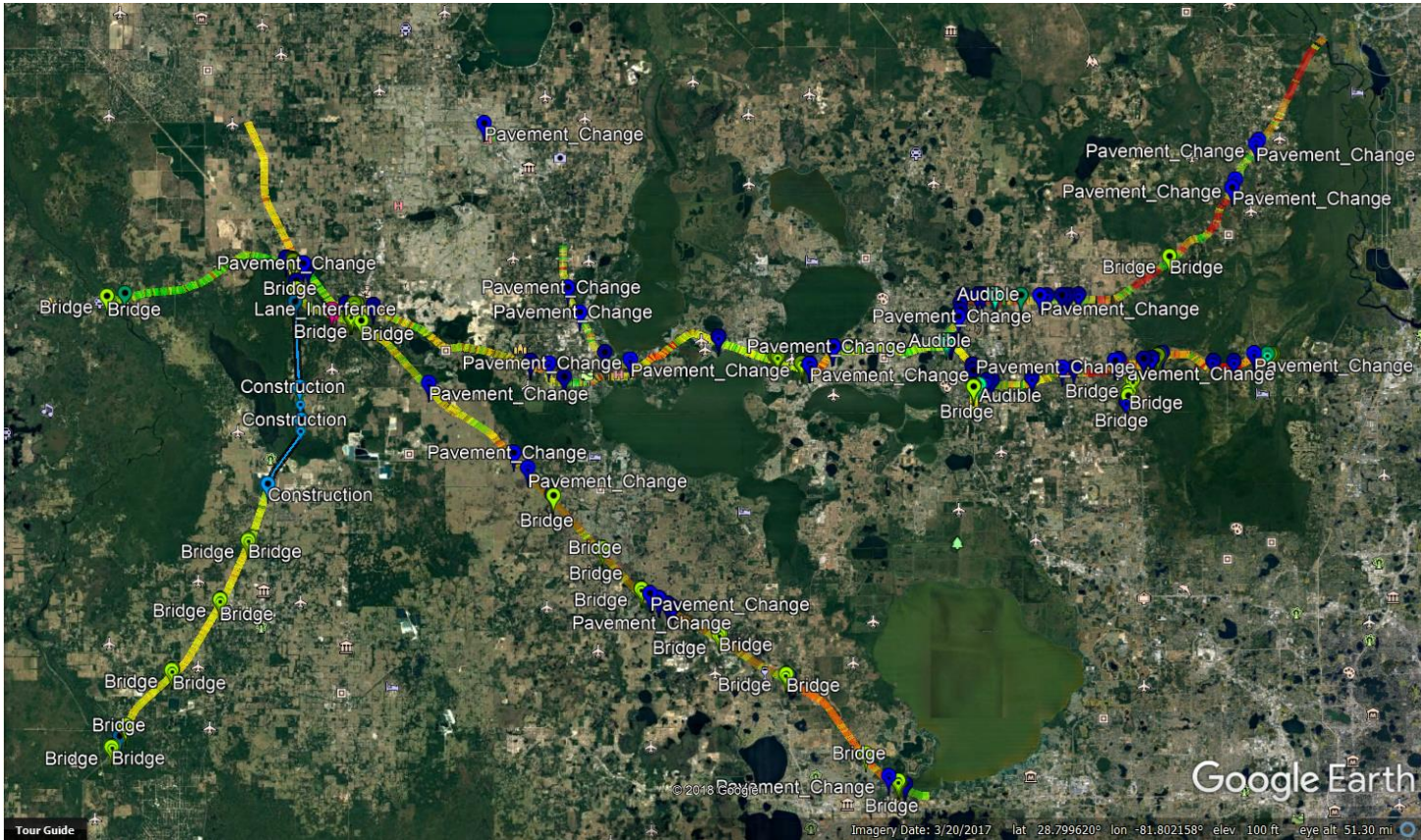


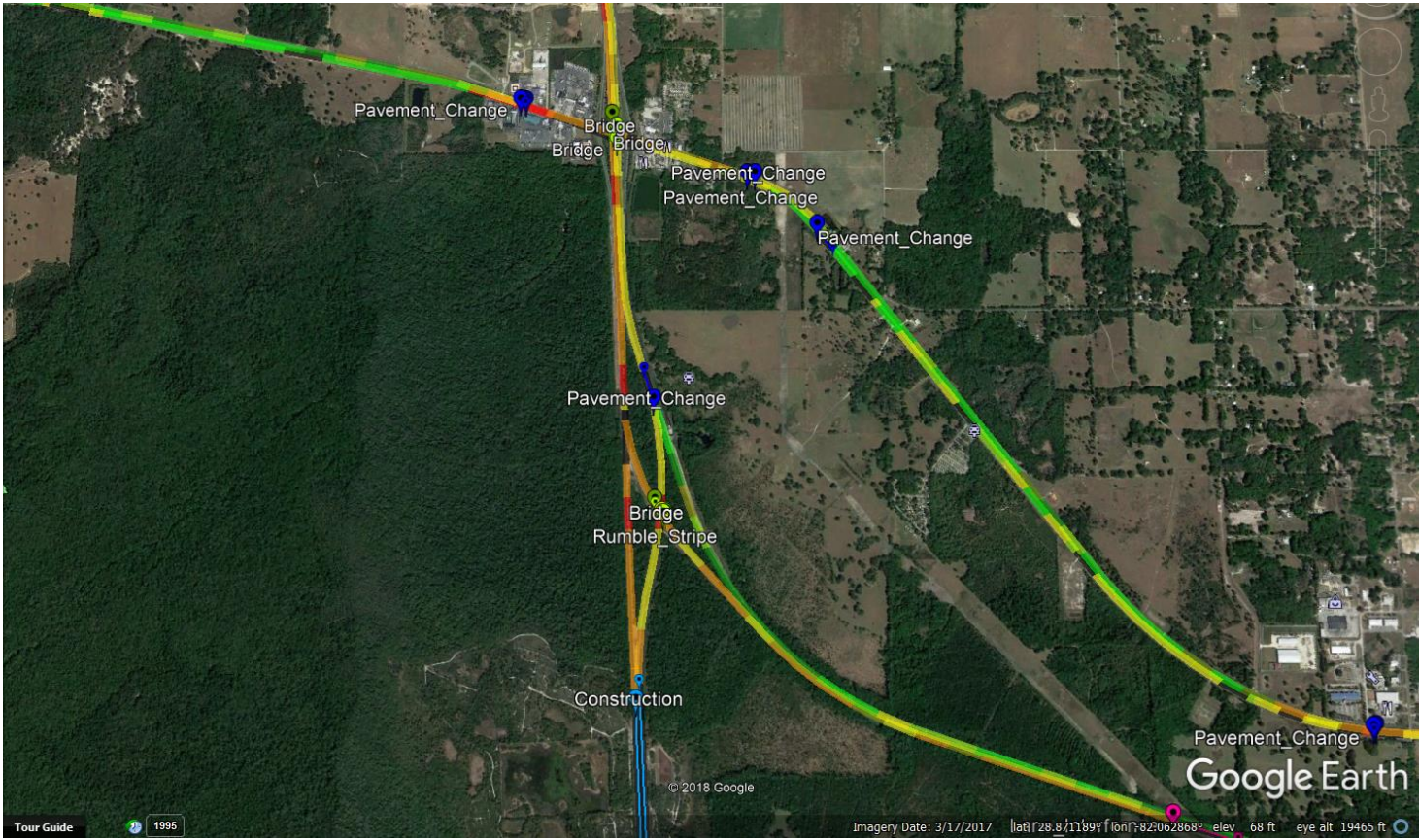
- AASHTO T398 describes the nomenclature for notating the pavement marking information:
 - Direction of travel
 - L = Descending mileposts
 - R = Ascending mileposts
 - Alternatively, agencies may choose to notate the direction of travel with N, S, E, or W compass directions
 - Stripe Type
 - EL = Edge Line (white)
 - CL = Centerline (yellow)
 - SL = Skip Line (white)
 - If there are multiple lanes with multiple skip lines, the lanes get numbered. Examples to follow.





Remember center lines must be measured in both directions of travel – retroreflectivity values will not be the same





With a handheld retroreflector:

- Begin with a nighttime visual assessment.
 - This is the quickest way to identify the areas that need attention.
 - Can be either the “Consistent Parameters” method (with 60 year old observer) or “Calibrated Pavement Markings” method
- Once the poor performing areas are identified, those should be the first ones to be evaluated with a handheld retroreflector per guidelines in ASTM D7585/D7585M
- Implement a restriping schedule based on your findings

If you have a mobile retroreflector (MRU):

- Measure the roads with the MRU. This can be done day or night.
- Report the findings per guidelines in AASHTO T398 and implement a restriping schedule

The MUTCD allows for different methods to be implemented for compliance

- It's not an either / or situation. You can choose multiple methods or a hybrid approach.

Retroreflectometers can be an expensive purchase, but lower cost options are available to obtain the use of one

- Many companies and agencies offer rentals of the equipment
- Measurement services can be contracted out on an as-needed basis

- Pavement marking retroreflectivity **cannot** be visually assessed in the daylight!
- Notice in the videos below, both skip lines look adequate during the day, but at night, the one on the left has much better retroreflectivity than the other.
- This is why the MUTCD does not allow for daytime evaluations of pavement marking retroreflectivity



“one size fits all” approach to managing and maintaining a hybrid approach

where aspects of different methods are combined can be the most

Use of a retroreflectometer is the most quantitative way to determine

retroreflectivity

- Agencies should evaluate the different options and choose what works best for them
- For example, an agency could begin with a thorough nighttime visual inspection then go back with a retroreflectometer, either by owning one or on an as-needed basis through rental or contract services.
- Good quality retroreflectometers will provide you with the lowest uncertainty data and make the job of

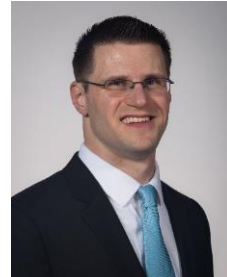
Eric Nelson

Phone: +1-858-279-6044

Email: enelson@roadvista.com

Selecting Durable Markings To Aid in Compliance with Min Retro Rule

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TRB Webinar
May 24, 2023



ROADMAP

Feelings about Min Marking Retro Rule
What's a Durable Marking?
Running Test Decks – Principles
Running Test Deck – Case Study
Final Comments



THERE ARE MIXED FEELINGS ON THE MINIMUM MARKING RETRO RULE

Group 1 worries about lawsuits and liability, wasted money and impossible mandates.

Group 2 is excited - they applaud better safety

Group 3 has complicated or ambivalent feelings, because they worry the rule is so low it will lower safety standards in places where higher numbers already existed or because the compliance conditions are too weak...

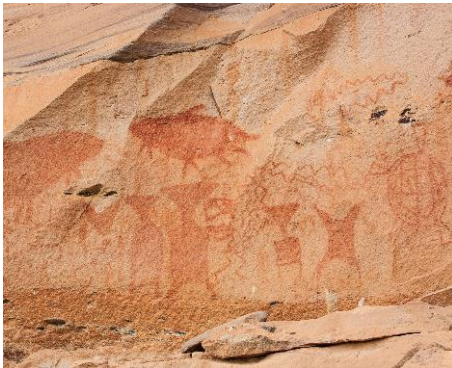


THE LAST 30 YEARS HAVE LED TO TONS OF CHANGE... AND VERY LITTLE

- (Semi-) autonomous vehicles are using pavement markings as “the rails”
- Mobile retro units can measure markings dramatically quicker than handheld units
- Innovations in paint and coatings have introduced and obsoleted generations of products in other markets.

But... a lot of specifications, a lot of markings being used, and a lot of evaluation programs have changed little to none at all over decades

This is our chance to take advantage of the many innovations in the industry to tweak some practices and radically increase the performance of our marking programs



WHAT MAKES A MARKING DURABLE?

If you had to select which markings from a set were durable, what questions would you ask?

Would you ask **how much it cost per foot?**

Would you ask **what color it is?**

Would you ask **about product density?**

Would you ask **who made it?**

Would you ask the **type of marking?**

Would you ask about **initial retro?**

Would you ask about **retro over time?**



Marking
1
General Business

Marking
2

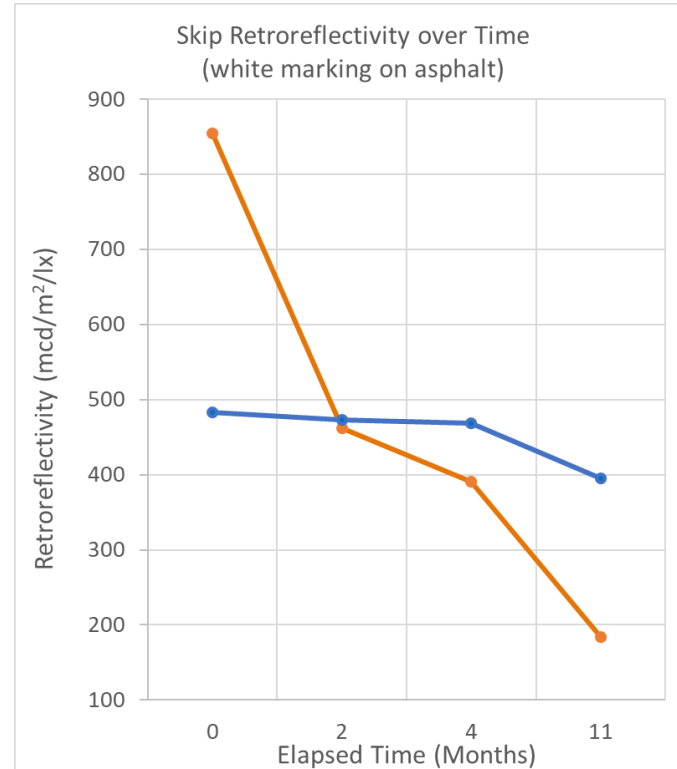
Marking
3

WHAT MAKES A MARKING DURABLE?

Consider this data from 2018 AASHTO NTPEP PMM Test Deck in PA:

One marking is a hot melt thermoplastic
One marking is a thin film waterborne paint

Can you guess which is which?
How confident are you?



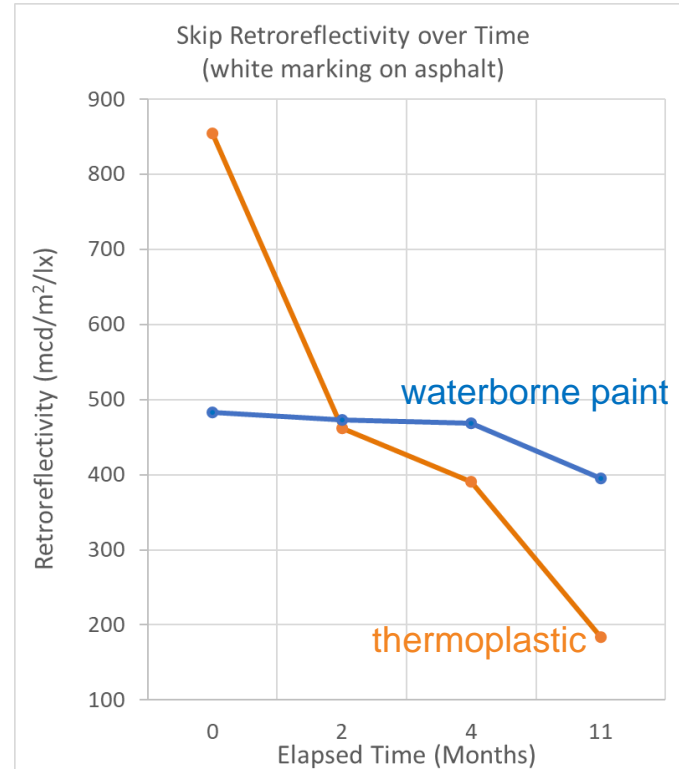
WHAT MAKES A MARKING DURABLE?

Consider this data from 2018 AASHTO NTPEP PMM Test Deck in PA:

One marking is a hot melt thermoplastic
One marking is a thin film waterborne paint

Can you guess which is which?
How confident are you?

Were you right?



WHAT MAKES A MARKING DURABLE?

Consider this data from 2018 AASHTO NTPEP PMM Test Deck in PA:

One marking is a hot melt thermoplastic
One marking is a thin film waterborne paint

Which questions mattered?

Would you ask **how much it cost per foot**?

Would you ask **what color it is**?

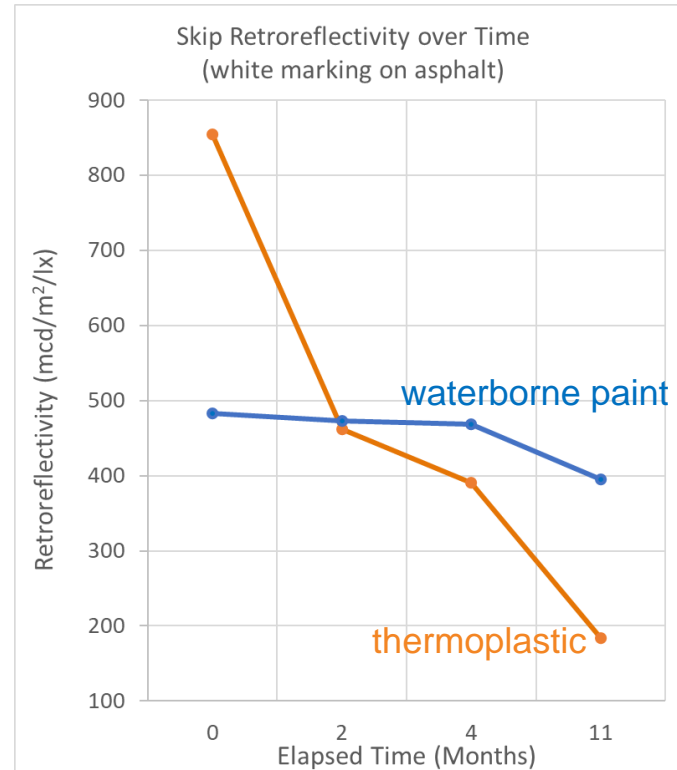
Would you ask **about product density**?

Would you ask **who made it**?

Would you ask the **type of marking**?

Would you ask about **initial retro**?

Would you ask about **retro over time**?



WHAT MAKES A MARKING DURABLE?

Consider this data from 2018 AASHTO NTPEP PMM Test Deck in PA:

One marking is a hot melt thermoplastic
One marking is a thin film waterborne paint

Which questions mattered?

Would you ask **how much it cost per foot**?

Would you ask **what color it is**?

Would you ask **about product density**?

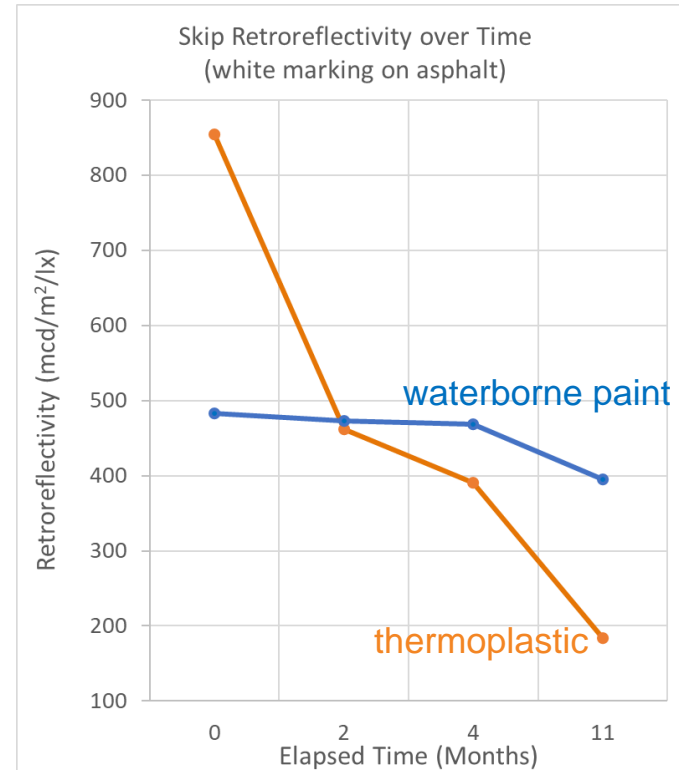
Would you ask **who made it**?

Would you ask the **type of marking**?

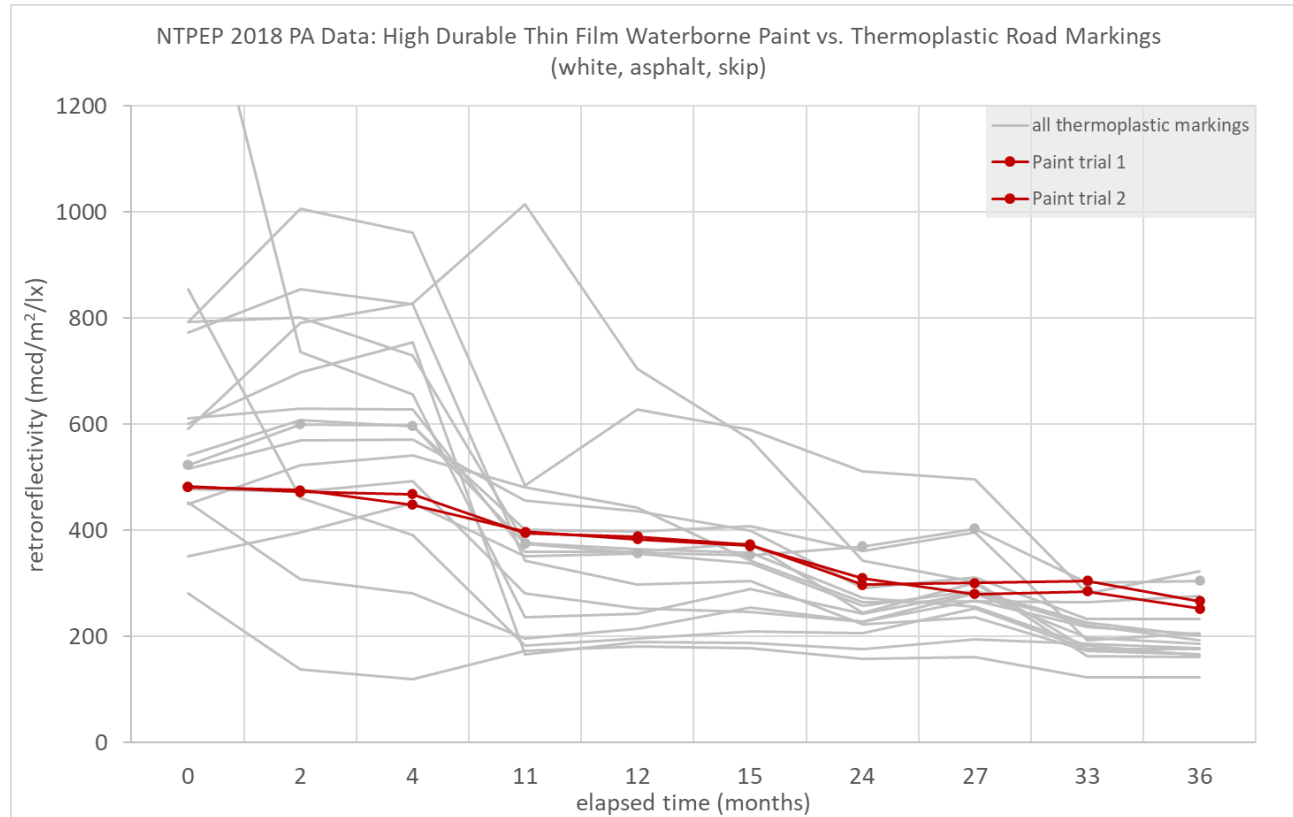
Would you ask about **initial retro**?

Would you ask about **retro over time**?

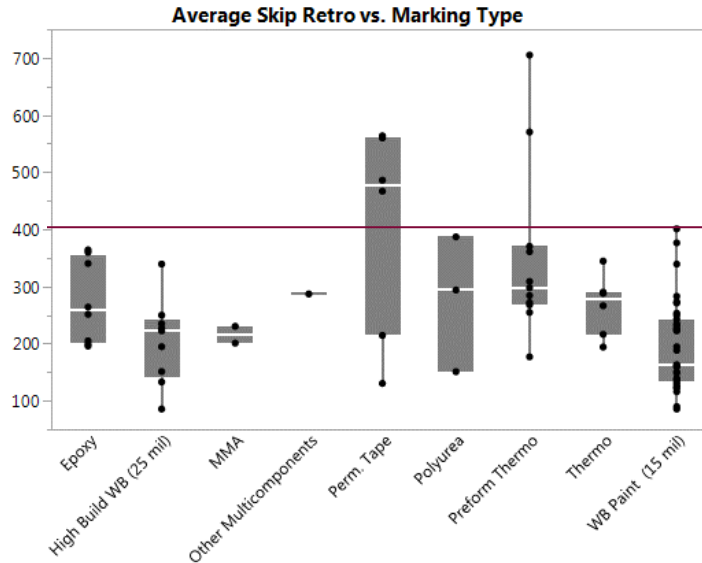
How many in our audience have been involved in a controlled scientific study of pavement marking durability recently?



FULL DATA REVEAL FROM DURABLE PAINT VS THERMO 2018



TREMENDOUS VARIATION IN DURABILITY WITHIN EACH TYPE OF MARKING



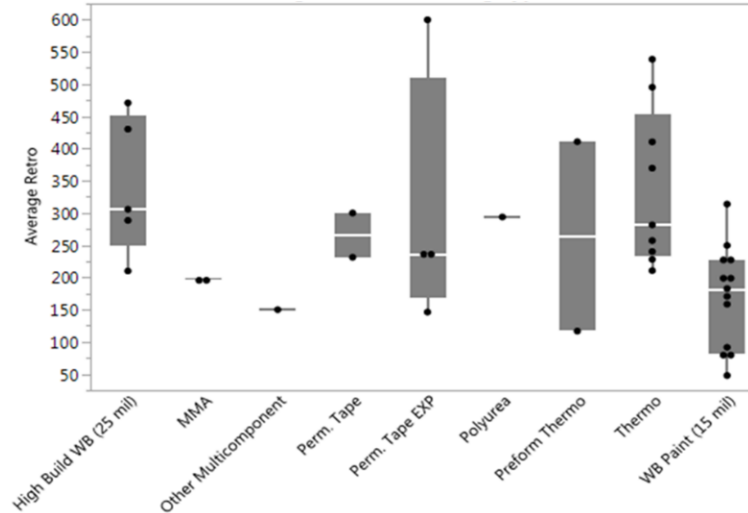
2-Year Skip
Data From
Northern
NTPEP Deck
(2017WI)

- Each technology class continues to show broad variation in performance, demonstrating more variation within each class than from class to class.
- After two years in a cold climate epoxy, cold plastic and high build waterborne provide similar retro and presence in the skip region.
- The best thin film waterborne beat every epoxy, cold plastic, thermoplastic polyurea and multicomponent coating and had ~10X the retroreflectivity of the worst waterborne.

Best waterborne marking had 6 lbs of M247 Type 1 beads

GREAT DURABILITY VARIATION TRUE ACROSS CLIMATES

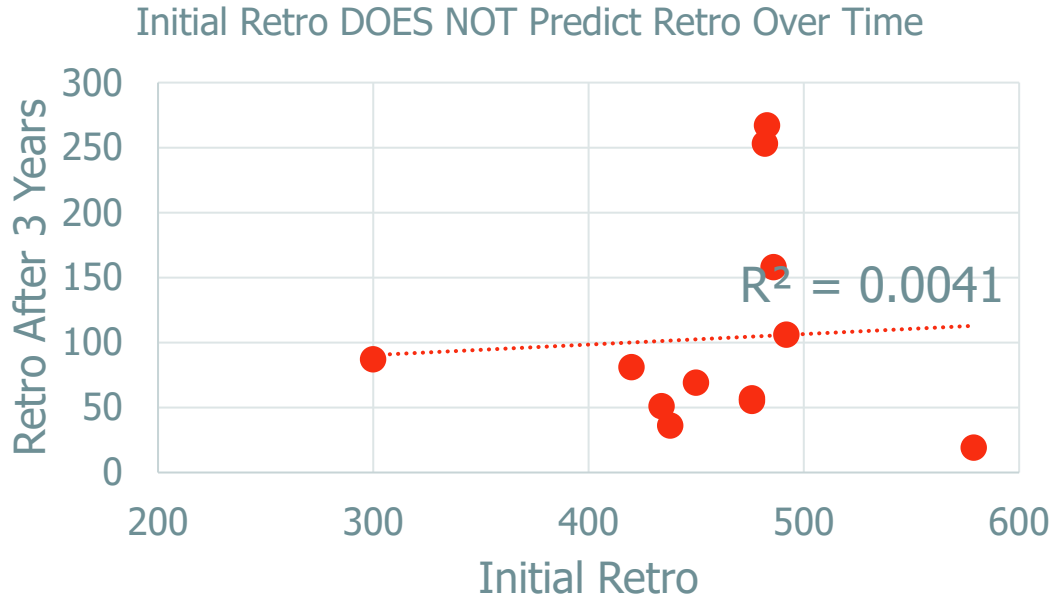
3-Year Skip
Data From
Southern
NTPEP Deck
(2012FLA)



- High build waterborne paint has the highest median value of all technology classes
- Every technology class represented by more than two products has a dramatic range between the best and worst material in class. There is a stark performance difference between high build and thin film waterborne.

None of the high performing products utilize atypical beads; the top performing thin film waterborne paints use only AASHTO M247 Type 1 beads, the top performing high build waterborne use a blend of AASHTO M247 type 1 and type 3 beads, and the top four thermoplastics use M247 type 3 beads blended with type 1 or 2 beads.

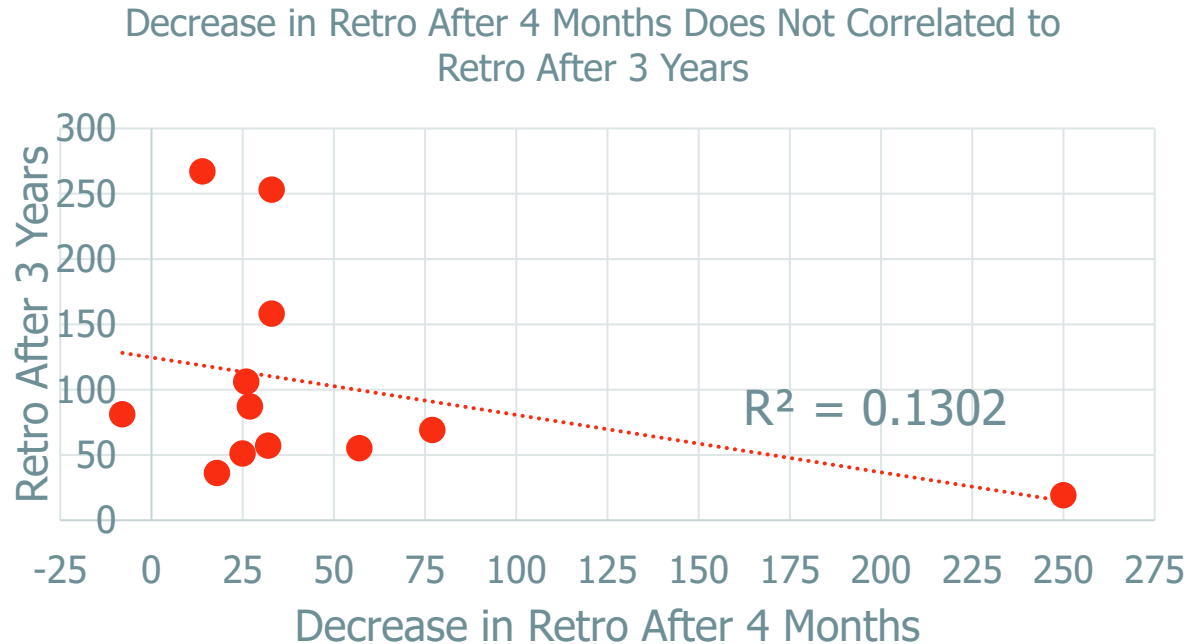
INITIAL RETRO DOES NOT PREDICT SERVICE LIFE



Initial retro does not predict durability

Even just for one color of one type of marking on one road
(waterborne white paints on asphalt, per 2018 PA NTPEP)

INITIAL RATE OF DECAY **DOES NOT** PREDICT SERVICE LIFE



Measuring retro right before winter does not predict retro over time
Even just for one color of one type of marking on one road
(waterborne white paints on asphalt, per 2018 PA NTPEP)

IT'S NOT EASY TO RUN A GREAT TEST DECK

It's really easy to make a mistake when running a test deck or when comparing data from test decks.

It's critical to be sure that your test deck has sufficient testing and fingerprinting to ensure QA / QC

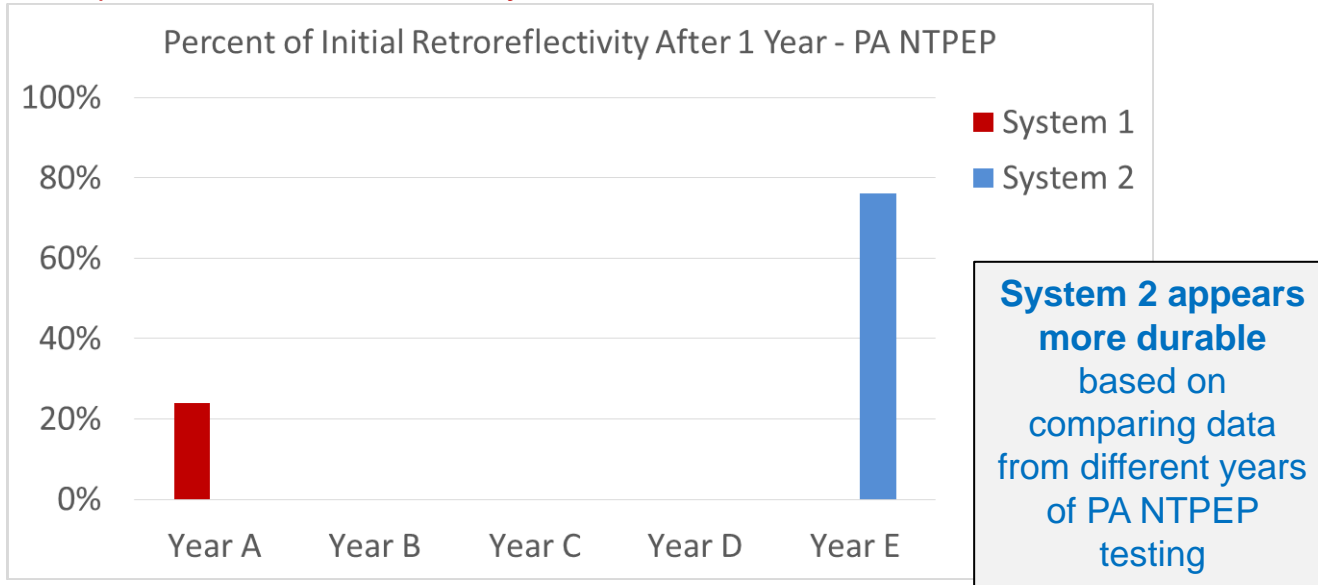


BE CAREFUL COMPARING MATERIALS ACROSS DECKS

Materials applied to one deck are often **compared to materials applied to a different deck**. This lacks control and is one reason some states require reapproval of markings

Below is data showing two different waterborne paints applied to PA NTPEP test decks in different years.

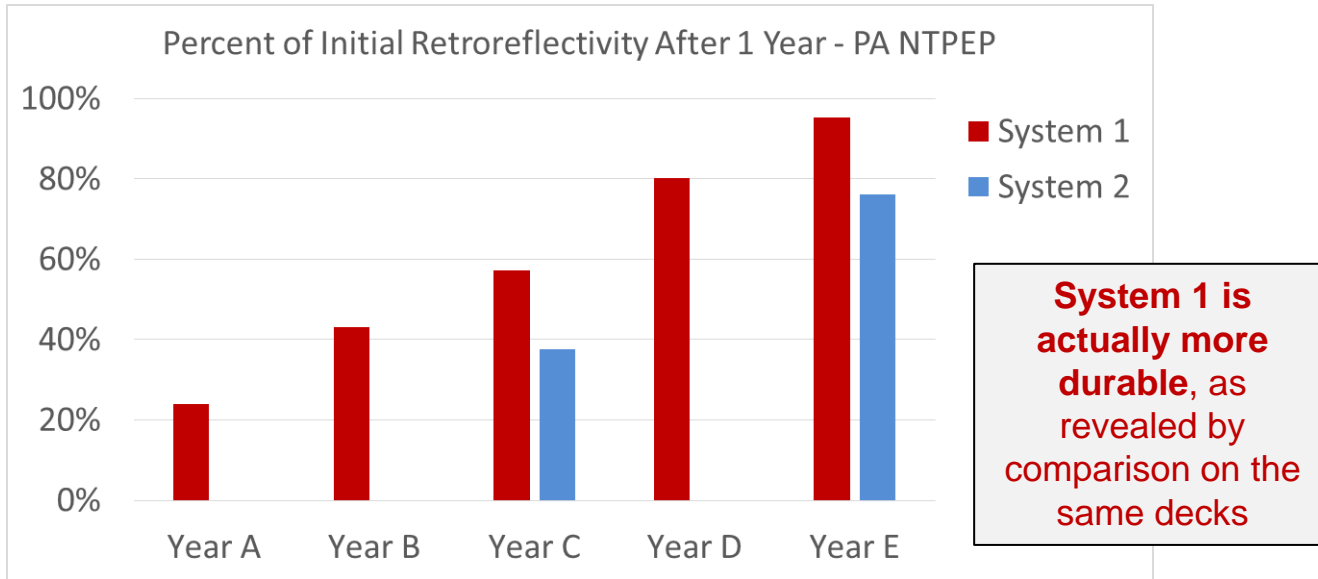
Which paint is more durable? *Are you sure?*



PAINT PERFORMANCE CAN VARY FROM DECK TO DECK

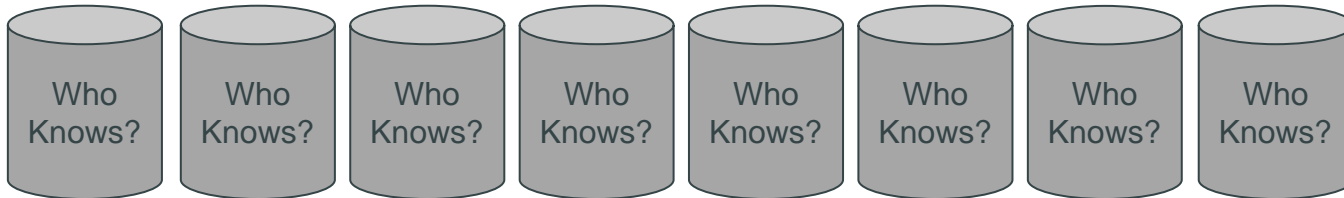
Data comparing materials on the same deck greatly increases the odds of drawing valid conclusions

We applied system 1 to five consecutive PA NTPEP PMM decks. Despite being applied to similar roads in the same state every year results were wildly different.



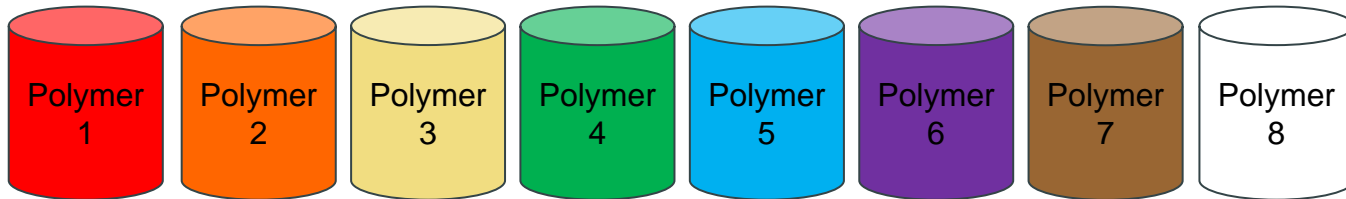
FINGERPRINTING IS REQUIRED FOR QA/QC

- Fingerprinting and spot testing are required to ensure you receive the paint you tested and intend to purchase



FINGERPRINTING IS REQUIRED FOR QA/QC

- Fingerprinting and spot testing are required to ensure you receive the paint you tested and intend to purchase
- Polymer type is more important to durability than all or at least a majority of current NTPEP tests
- Current NTPEP work plan does not test for polymer type
- FTIR testing can differentiate some markings, but more tools are needed for true verification



BC DECK: PAINT SOLICITATION AND ANONYMIZATION

- BCMoTI solicited paints (max of 2 white and 2 yellow per company) from at least 7 different formulators including all previous bidders as well as bidders for nearby government bids
- Nearby states and provinces were invited to send paints they were using in 2018 and several of those were also tested as well as the primary paint used on BC roads in 2018.
- All Paints were anonymized prior to application such that none of the applicators or administrators of the decks knew the identity of any paint. This was to prevent any claims of intentional or unintentional bias during application or evaluation of lines.
- Paint densities measured to assist in calibration



BC DECK: GEOMETRY AND APPLICATION OF ROAD TRIALS

- Decks were applied in both Penticton, BC and Doylestown, PA. Installations done in October with temperature > 50°F
- Each paint was applied four times to each location – 2x on subdeck A and 2x on subdeck B
- BC test deck was applied by Lafrentz under supervision of Dow and BCMOT. Self-propelled airless spray equipment with adjustable speed and gravity drop beads, ~8 different tips.
- Pennsylvania deck was applied by Dow utilizing a constant-speed, air assisted striper and pressurized beads. This equipment allows greater control and better glass bead embedment
- Installing two test decks should increase signal to noise, providing higher confidence that results will show true durability ranking of paints. Two decks also provide multiple road surfaces and winter weather / maintenance seasons



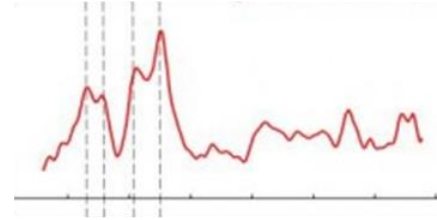
BC DECK: EVALUATION OF DECKS

- Both test decks were evaluated periodically to ensure we did not miss a critical time window – for example if heavy traffic or rough winter wore all lines.
- Every line was photographed at every reading – photos utilized equipment to ensure uniform distance, lighting, angle. Wide angle photos also taken for cross-reference.
- Retroreflectivity of each line was measured at each reading
 - Lane center and left wheel track in BC; By edge line and right wheel track in PA
- Presence of each line was graded at each reading
 - Each photo was graded by 2 individuals with scores averaged
- Results for each paint (4 lines per deck) were averaged at every reading



BC DECK: LABORATORY TESTING OF PAINTS

- **Paints had extensive laboratory fingerprint testing**
 - Fingerprinting is critical to ensure paints used match paints tested
- Density
- Viscosity
- Hegman
- Dry to no pickup
- Weight percent solids
- Weight percent pigment
- Opacity
- Y reflectance
- Scrub resistance
- Taber abrasion resistance
- Polymer Type – FTIR & Fluorescence
- *All tests were run in duplicate*



Only polymer type was correlated with durability

Results: White Paint Performance - Summary

- Broad range of performance in terms of durability was observed across the paints
- The six most durable paints
 - All contained the same type of polymer
 - Were formulated by at least 5 different companies
- Paints sent by formulators for this trial tended to be more durable than the paints obtained that were used by various MOT/DOT in 2018
 - Suggests states may be able to obtain better paint
- Durability Score is a single metric meant to rank paints

Paint ID	Durability Score	PA Edge Retro	PA WT Retro	PA WT Presence	Pentiction Center Retro	Pentiction Center Presence	Paint Source	Polymer Type
White A	0.986	314.5	208	86.25	175.75	95.125	F3	4
White E	0.951	247	197	85.625	177.75	93.875	F2	4
White F	0.945	258	214.75	83.75	165	92.625	F5	4
White V	0.925	250.5	169.75	85.625	154.25	93.875	DOT	4
White Q	0.912	253.25	157.25	82.5	159	94.5	F6	4
White P	0.893	272	186.25	85.625	111.75	87.25	F1	4
White Y	0.818	244.5	143.75	65.625	180.75	85.625	DOT	1
White D	0.810	255.75	186.5	81.875	73.25	75.625	F5	1
White C	0.808	278.5	121.75	71.875	142.25	81.875	F3	2
White R	0.696	147.75	74.5	51.25	193.5	84.375	DOT	1
White Z	0.680	225	91.5	58.125	121.5	73.75	DOT	2
White H	0.666	241.25	145.5	56.875	77.25	68.75	F4	1
White T	0.562	164	64.5	52.5	46.5	68.75	F6	3
White G	0.488	99.25	41.5	13.375	139	85.625	DOT	1
White L	0.441	80.75	31.5	28.75	57.5	71.875	DOT	1
White J	0.387	72.5	16.5	6.875	72.25	81.25	F4	1
White X	0.345	62.75	22	5.5	66.25	71.875	DOT	1
White B	0.325	27.5	9	2.125	68.25	75	DOT	1
White N	0.271	78	22.25	11.25	38.25	47.5	F1	1
Green	0.85	250	150	85	150	90		
Yellow	0.6	200	100	60	100	70		
Thresholds								

Results: Yellow Paint Performance - Summary

- Broad range of performance in terms of durability was observed across the paints
- The six most durable paints
 - All contained the same type of polymer
 - Were formulated by 5 different companies
- Paints sent by formulators for this trial tended to be more durable than the paints obtained that were used by various MOT/DOT in 2018
- Suggests states may be able to obtain better paint
- Durability Score is a single metric meant to rank paints

Paint ID	Durability Score	PA Edge Retro	PA WT Retro	PA WT Presence	Pentiction Center Retro	Pentiction Center Presence	Paint Source	Polymer Type
Yellow D	0.968	194.75	107.75	83.125	66.75	91.625	F5	4
Yellow R	0.943	167	101.25	78.125	71	95.125	F6	4
Yellow X	0.898	129.75	87.75	79.375	81.5	86.875	F1	4
Yellow H	0.880	145.75	86	76.25	59	91.875	F3	4
Yellow Q	0.876	148.5	81.5	75.625	58.5	92.625	F2	4
Yellow W	0.853	129.75	73.25	74.375	64	90.625	F5	4
Yellow E	0.797	151.5	91.25	65	49	82.5	F3	2
Yellow V	0.633	112.5	56.5	54.375	39.5	68.125	F6	3
Yellow B	0.621	100.75	32.25	35	52.75	90.625	F4	1
Yellow Y	0.591	95.5	37.25	41.875	38.5	79.375	DOT	1
Yellow L	0.475	89.25	39.75	20	40.5	70.625	DOT	1
Yellow O	0.458	112.75	40.75	23.125	30.75	61.875	DOT	1
Yellow J	0.445	49.75	15	15.25	40.5	81.25	F1	1
Yellow N	0.432	73.5	27.25	17.5	27.5	72.5	DOT	1
Yellow G	0.355	25.75	10.75	5.25	31.5	75.625	DOT	1
Yellow F	0.348	42.5	19.75	12.5	31.5	60	DOT	1
Green	0.85	120	100	70	60	90		
Yellow	0.6	80	75	30	40	70		
Thresholds								

HOW CAN YOU PROCURE COST EFFECTIVE DURABLE MARKINGS?

Many specifications don't factor durability or service life at all!

Warranty contracts can drive cost effective markings if proper enforcement protocols are in place

Some contracts use test decks to select or exclude markings based on tested durability

Some procurement contracts adjust bids based on test deck performance

"In order to emphasize quality, the Department will apply a Price Adjustment Factor (PAF) as a multiplier to each paint bid price prior to selecting the "low bid." The Department's formula for statewide bids for "white and yellow traffic paint," i.e., Contract #8010-04, is as follows:

$$\text{PAF: } [1000/((0.85\text{RB} \times \text{DB}) + (0.15\text{RC} \times \text{DC}))]^{0.75}$$

RB and RC are the average skip retroreflectivity on bituminous and Portland cement pavements

DB and DC are the average wheel track durability rating on bituminous and Portland cement pavements

Summary and Suggestions

- Selecting cost effective durable markings can greatly reduce the cost to comply with minimum marking retro rule
- The type of marking (thermo vs paint vs tape vs epoxy) is not a good proxy for service life
- Controlled scientific studies of marking durability are the best tool for selecting durable markings
- Knowing which markings are durable doesn't help unless you figure out a good procurement protocol



**Thank
You**



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MARKING MATERIAL COSTS

- Numerous surveys have explored costs road authorities pay for different types of marking materials.
- Installed costs of marking materials is largely dependent on type of technology, and is much less dependent on the quality within each technology class.
- Both tables below are directly reprinted from Idaho Department of Transportation Research Report RP182A by H. Sadid, R.M. Wabrek, S. Dongare, edited by B. Coryell and A. Erahimpour at Idaho State University

Table 10. Cost Summary for Installed Pavement Markings in Idaho and Other Selected States:⁽¹¹⁾

State	Conventional Paint	Epoxy Paint	Thermoplastic	Spread Thermoplastic	Profile Tape
Pennsylvania	0.02	–	–	–	--
Kansas	0.05	0.32	0.41	0.19	2.12
Minnesota	0.05	0.19	–	–	--
Virginia	0.18	0.30	–	0.26	0.67
Wyoming	0.04	0.40–0.45	–	–	--
North Dakota	–	–	–	–	--
Idaho	0.04	–	–	–	--
Montana	–	0.10–0.14	1.50	–	--

All prices are in \$/ft

– Information not available.

Table 11. Unit Cost of Markings: (\$/ft for Longitudinal Marking)⁽¹¹⁾

Marking Material	Roadway Delineation practices Handbook (1994) ⁽²⁵⁾	NCHRP Report 392 (1997) ⁽²⁶⁾	Cottrel and Hanson (2001) ⁽²⁷⁾	NCHRP Synthesis 306 (2002) ⁽¹⁴⁾	Carlson et al. (2007) ⁽²⁰⁾
Waterborne paint	0.04 - 0.06	0.06	0.04 - 0.15	0.06	0.08
Thermoplastic	0.32 - 0.60	0.30	0.35	0.32	0.27 - 0.32
Performed tape, profiled	–	1.75	1.80	2.33	2.75 - 3.75
Epoxy	0.40 - 0.45	0.25	0.40	0.26	--
Conventional Solvent paint	–	–	–	0.07	–
Methyl methacrylate	–	0.75	–	1.22	1.50 - 2.10
Thermoplastic	–	–	–	0.87	0.75
Polyester	–	0.10	–	0.13	–
Polyurea	–	–	0.70	0.90	0.85

Today's presenters



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July 8, 2023

TRB's National Conference on
Transportation Asset Management



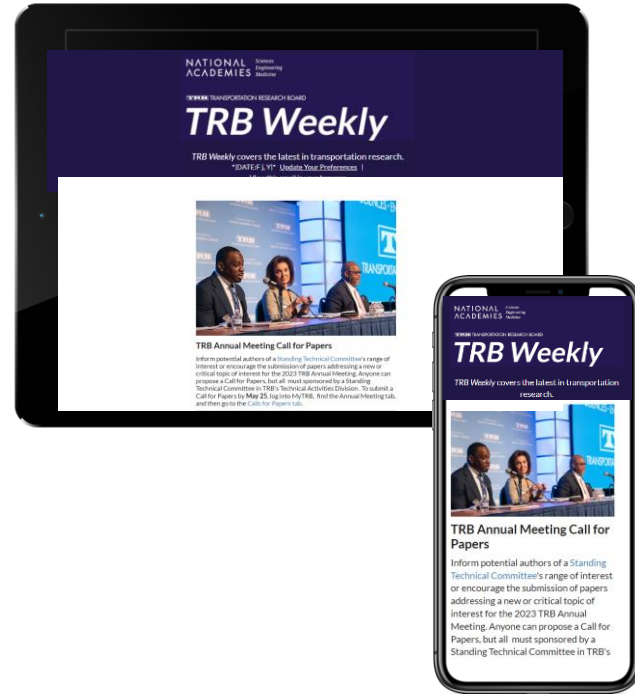
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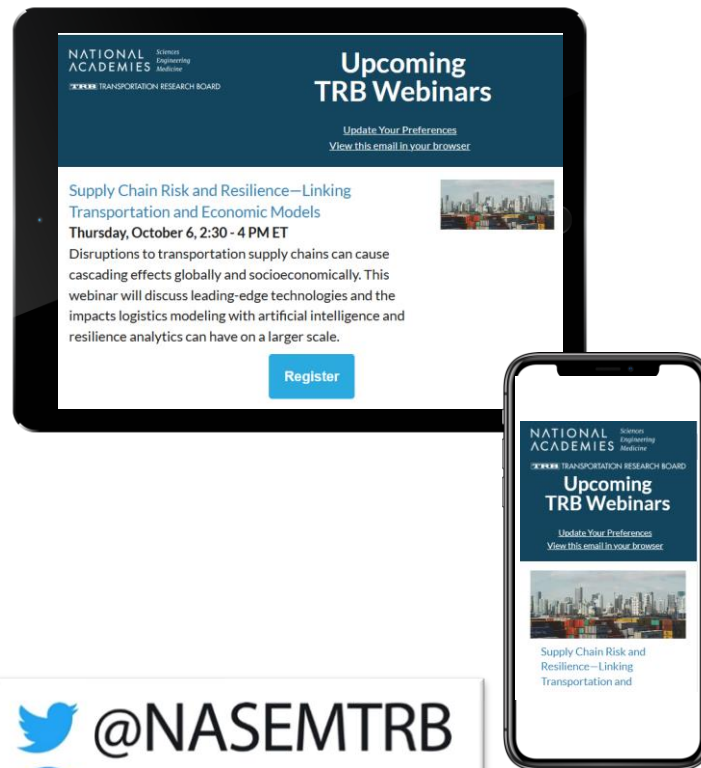
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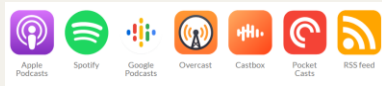
<https://www.nationalacademies.org/trb/get-involved>

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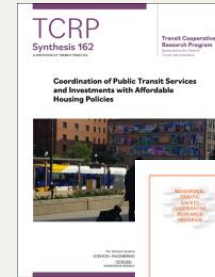
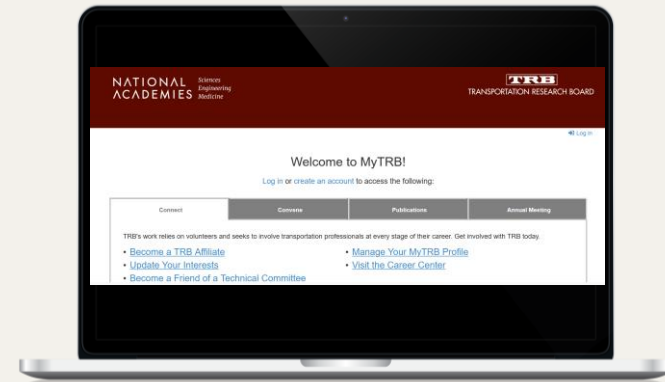
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